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Surveys of Benthic Macroinvertebrates in Playgreen and Kiskittogisu Lakes, Northern Manitoba

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by

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p. 14, Table 7 - Misc. column should read:

1987	North	250 (51)
	South	16 (7)
1989	North	26 (7)
	South	16 (5)

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ABSTRACT

Wiens, A.P., and D.M. Rosenberg. 1991. Surveys of benthic macroinvertebrates in Playgreen and Kiskittogisu lakes, northern Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 1814: iv + 21 p.

Playgreen Lake was sampled for benthic macroinvertebrates in 1987 and 1989, and Kiskittogisu Lake was surveyed in 1989; the results were compared to a previous survey done in 1971 to assess the effects of water level regulation and diversion of Nelson River flow on the taxon abundance and structure of benthic invertebrate communities. Regulation of the lakes under historical high water levels had little effect on the benthic invertebrates. Densities of invertebrates within the plume of the flow from 2-mile Channel into Playgreen Lake appeared slightly higher than in areas adjacent to the plume. Diversion of Nelson River water out of Playgreen Lake into previously isolated Kiskittogisu Lake through 8-mile Channel resulted in decreased populations of invertebrates, particularly Amphipoda, in the northern part of Playgreen Lake. Significant increases in standing stocks of all invertebrate taxa occurred in the southern area of Kiskittogisu Lake that received the flow. Drought conditions and above-normal summer temperatures may have reduced Amphipoda and possibly sphaeriid mollusc populations in 1988-1989 in Playgreen Lake.

Key words: Lake Winnipeg; Jenpeg; hydroelectric; Chironomidae; Ephemeroptera; Pelecypoda; Oligochaeta; nutrients; sediments.

RÉSUMÉ

Wiens, A.P., and D.M. Rosenberg. 1991. Surveys of benthic macroinvertebrates in Playgreen and Kiskittogisu lakes, northern Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 1814: iv + 21 p.

Dans le lac Playgreen, ont été échantillonnés en 1987 et 1989 des macroinvertébrés benthiques; le lac Kiskittogisu a été exploré en 1989. Les résultats ont été comparés à ceux d'un relevé précédent effectué en 1971 pour évaluer les effets qu'ont exercés la régulation du niveau de l'eau et le détournement de la rivière Nelson sur l'abondance des taxons et sur la structure des communautés d'invertébrés benthiques. La régulation des lacs, au cours de la période historique qui est caractérisée par des niveaux d'eau élevés, a eu un effet minime sur les invertébrés benthiques. Dans la traînée d'eaux provenant du Chenal de 2 milles et se déversant dans le lac Playgreen, la densité des populations d'invertébrés est apparue plus élevée que dans les régions adjacentes à la traînée. En raison du détournement des eaux de la rivière Nelson à partir du lac Playgreen dans le lac Kiskittogisu jusque-là isolé, à travers le Chenal de 8 milles, les populations d'invertébrés, en particulier d'amphipodes, ont diminué dans la partie nord du lac Playgreen. Dans la partie sud du lac Kiskittogisu qui a reçu les eaux détournées, les stocks actuels de tous les taxons d'invertébrés ont subi des accroissements significatifs. Il est possible que les conditions de sécheresse et les températures estivales supérieures à la normale aient réduit les populations d'amphipodes et peut-être de mollusques sphaeriidés dans le lac Playgreen en 1988 et 1989.

Mots-clés: lac Winnipeg; Jenpeg; hydroélectrique; Chironomidae; Ephemeroptera; Pelecypoda; Oligochaeta; éléments nutritifs; sédiments.

INTRODUCTION

Playgreen and Kiskittogisu lakes precede the outflow of Lake Winnipeg into the Nelson River. In the late 1600's and through the 1700's, the upper part of the Nelson River became the major access route for explorers entering North America from Hudson's Bay. The upper Nelson River was a main transportation corridor for the fur trade, and in the mid 1800's, it provided access to the Red River valley of Manitoba for settlers who founded the City of Winnipeg.

During more recent times, this area of northern Manitoba has been the scene of hydroelectric development. The hydroelectric potential of northern Manitoba was identified early in the 20th century (Hecky et al. 1984). The first generating station on the Nelson River, Kelsey, was built in 1961 to supply power to the INCO mine and smelter at Thompson (Newbury et al. 1984). Federal-provincial studies were initiated in 1964 to examine the feasibility of developing additional generating stations on the Churchill and Nelson rivers. By 1966, nine dam sites had been identified on the Nelson River, and several diversion schemes were proposed for routing the Churchill River into the Nelson River to increase flows through the proposed Nelson River dams. The decision to proceed with full Nelson River development was announced by the Government of Manitoba in 1966.

Churchill River diversion and construction of the Jenpeg, Kettle Rapids and Long Spruce Rapids generating stations were completed in the late 1970's. Construction of the Limestone Rapids generating station was started at that time, halted because of falling power demands, restarted, and is now essentially complete. More sites are scheduled for development in the future.

Most of the flow out of Lake Winnipeg goes through the West Channel of the Nelson River via Playgreen Lake and Ominawin and Metchanais Rapids to Cross Lake (Fig. 1). The Jenpeg site on the West Channel regulates the level of Lake Winnipeg in order to provide dependable mid-winter flows to the lower Nelson (Dickson 1975). In order to increase outflow capacity of Lake Winnipeg, 2-mile Channel (2MC) was excavated between Lake Winnipeg and Playgreen Lake, 8-mile Channel (8MC) was excavated between Playgreen and Kiskittogisu lakes, and the Ominawin Bypass was constructed to divert flows around Ominawin Rapids to the West Channel. The operation of the Jenpeg dam, and construction of 2MC and 8MC provide the background conditions for benthic invertebrate studies in Playgreen and Kiskittogisu lakes. The purpose of this study was to compare the pre- and post-Lake Winnipeg regulation status of benthic invertebrates in Playgreen and Kiskittogisu lakes.

STUDY SITES

Playgreen and Kiskittogisu lakes straddle the transition between the Manitoba Lowland Plain and the Canadian Shield in north-central Manitoba. They lie in a depression called the Nelson Trough. The area is covered by a thick layer of silts and clays that are remainders of glacial Lake Agassiz; terrain profiles are smoothed by these sediments. Organic deposits are extensive on the western shores of both lakes, and the terrain on those shorelines consists mostly of peatlands. Both lakes have large, shallow southern or southwestern basins that lie in the flat, lowland areas. Water flows northeastward from these basins to the rocky, narrow passages of the Canadian Shield.

The large, southern basin of Playgreen Lake narrows about 40 km north of Warren Landing, forming a middle section about 25 km long, then opens again in the north to a wide, island-studded area immediately before the formation of the West Channel at Whiskey Jack Narrows (Fig. 1; Table 1). Prior to hydro development, ≈84% of the flow ($1721\ m^3 \cdot sec^{-1} \cdot yr^{-1}$) went through the lake and exited via the West Channel; the remainder (≈16% of the total or $337.4\ m^3 \cdot sec^{-1} \cdot yr^{-1}$) flowed out of the south basin into the East Channel and northward to rejoin the Nelson River at Cross Lake (Ayles 1973; Koshinsky 1974). Flow through the East Channel remained virtually the same after regulation (≈18% of the total or $341.8\ m^3 \cdot sec^{-1} \cdot yr^{-1}$; Water Survey of Canada 1987a,b, 1988-1990).

Construction of 2MC and 8MC, however, have altered flow patterns through Playgreen and Kiskittogisu lakes. Warren Landing, the natural outlet of Lake Winnipeg into Playgreen Lake, is shallow and hydraulically inefficient during periods of low water levels. During such periods, 2MC contributes most of the flow to Playgreen Lake (≈68% in 1977: MacLaren Plansearch Inc. 1985). During periods of normal and high water levels in Lake Winnipeg, Warren Landing carries about twice as much flow as 2MC (63-70%). Therefore, 2MC relieves hydraulic inefficiency during low-water periods. It also introduces material eroded from the north shore of Lake Winnipeg into the south basin of Playgreen Lake.

Kiskittogisu Lake also empties into the West Channel, although its historic discharge was negligible relative to that of Playgreen Lake. Prior to construction of 8MC, water from Kiskittogisu and Playgreen lakes mixed only in the far northern part of Kiskittogisu Lake. Now, 30% or an average of $464.3\ m^3 \cdot sec^{-1} \cdot yr^{-1}$ of the flow through the West Channel can be attributed to water from Kiskittogisu Lake (Water Survey of Canada 1987a,b, 1988-1990; D. Windsor, Manitoba Hydro, Winnipeg, personal communication). The formerly isolated southern basin of Kiskittogisu therefore receives substantial quantities of flow from Playgreen Lake because of the 8MC.

MATERIALS AND METHODS

Pre-development fisheries and benthic surveys of Playgreen and Kiskittogisu lakes were carried out in 1971 (Ayles 1973; Stockner 1973). Playgreen Lake was divided into three areas for survey purposes; Kiskittogisu Lake was divided into two areas (Stockner 1973; Fig. 1).

Benthic invertebrates were sampled at "key" and "transect" stations used for collecting fish (Ayles 1973, p. 10), although the exact locations and numbers of replicates taken were not specified. A total of 173 Ponar grab samples were taken, washed through a sieve of "200 meshes to the inch" (64 μm), and handpicked onsite without magnification (Ayles 1973, p.10). Sorted specimens were preserved in isopropyl alcohol and returned to the laboratory for identification and wet weight determination. The low standing stocks of benthic invertebrates reported from these surveys (see below) indicate either that the reported fine mesh size was in error or that the sorting procedure used was inefficient, or both.

Playgreen Lake was resurveyed in July 1987 and 1989, whereas Kiskittogisu Lake was resurveyed only in July 1989. Sampling was done along the same transects described in Ayles (1973), but additional transects were added in critical areas (e.g. just north of 8MC: Fig. 1).

Thirty-three stations were sampled in Playgreen Lake, approximately evenly distributed among the three areas (Fig. 1). The 12 stations sampled in Kiskittogisu Lake also were approximately evenly distributed between its two areas. Three Burton-Flannagan modified Ekman grab (15.2 x 15.2 cm) samples were taken at each station, accompanied by a Secchi disk reading, a temperature profile, a qualitative description of the sediments, and a sediment mini-core for particle size determination. Sediment compactness was measured using the 1 cm diameter rod of a Håkanson penetrometer (1987 in Playgreen Lake; 1989 in Kiskittogisu Lake). Water samples were taken from selected stations for routine chemical analyses during the 1987 Playgreen Lake survey (R.E. Hecky, Freshwater Institute, unpublished data).

Grab samples were sieved immediately through a 400 μm mesh, and the residues were preserved in a 4% formalin solution. Invertebrates were removed from the background material in the laboratory, using a stereomicroscope at 12X magnification. Peat-laden samples from the 1987 survey were subsampled by weight before sorting (Sebastien et al. 1988); final counts were adjusted accordingly.

Standing stocks of benthic invertebrates are expressed as no.·m^{-2} (±S.E.). Statistical analyses used the individual replicate as the lowest unit. For comparative purposes, the lakes were divided into the 1971 areas, and for Playgreen Lake, areas north and south of 8MC. The influence of 2MC was examined by dividing the southern Area 1 of Playgreen Lake into western, central and eastern thirds.

Multidimensional Scaling (MDS), a data reduction technique (Wilkinson 1986), was used to determine whether changes in flow patterns created changes in benthic invertebrate communities in the lakes, by examining the similarity of communities among individual stations and grouping the stations that were most similar as closely together as possible. Output from MDS was a set of XY coordinates for each station which, when graphed, produced a plot (Shepard diagram) on which stations with similar communities were clustered. Outlines were hand-drawn around groups of stations from Kiskittogisu Lake and the regions of Playgreen Lake north and south of 8MC that clustered most closely together. Regional similarities were then compared.

RESULTS

PHYSICAL CHANGES

The regulation of flow from Lake Winnipeg and the lakes at its outlet caused a rise in mean water level of only 0.46-0.50 m in Playgreen Lake, lower than the historic high water level. Kiskittogisu Lake, situated at a lower elevation, had an greater increase in mean water level (0.78 m), and the annual mean level after regulation approximates the historic high water level; maximum levels are higher (Koshinsky 1974). Regulation also reduced annual water level fluctuations and changed the monthly flow regime down the Nelson River.

Creation of the 8MC to facilitate flow out of Playgreen Lake altered the flow regime of Kiskittogisu Lake. Although Area 4 was influenced by Nelson River water prior to regulation, water renewal times for Area 5 decreased from almost 2 yr to about 3 weeks (Table 1). Conversely, diversion of the flow away from Whiskey Jack Narrows, coupled with the rise in mean water level doubled the renewal time for Areas 2 and 3 in the northern part of Playgreen Lake.

Monthly flow rates in the West Channel changed considerably after the Jenpeg dam was completed in 1977 (Table 2). Unregulated discharge (Table 2: 1972) peaked with snow melt and spring runoff (May-June), was maintained at a high level by the rains of summer (July-August), then decreased through the winter (November-March). After regulation (Table 2: 1987 and 1989) the flow situation was completely reversed. To meet the demand for increased hydroelectric

power in winter, the seasonal peak of discharge was shifted to the winter months, and the summer months became a period of low flow during which the reservoir refilled.

Discharge through the East Channel changed little over the years (Fig. 2); however, the total Nelson River flow varied because of low and high amounts of precipitation in the catchment basin, so the percentage of total flow through the East Channel varied from 15.3 to 28.3%.

Secchi disk readings are a good relative indication of turbidity, but can be influenced by wind action in shallow lakes with fine-grained bottom sediments. This variability can be seen in Table 3 where the surveys of 1970-1972 yielded readings of ≈0.5 m for Playgreen and Kiskittogisu lakes. In 1987, four days of calm weather preceded the survey, allowing the suspended sediments to settle, and the Secchi readings showed a progressive northwards increase in visibility. Diversion of sediment-laden water out of Playgreen Lake and into Kiskittogisu Lake probably also aided the increase in visibility. Strong winds before and during the 1989 survey resuspended bottom sediments, particularly in Area 3 of Playgreen Lake. The effect of wind in 1989 was also noticeable in Kiskittogisu Lake: open, shallow Area 5 had a mean Secchi reading of only 0.4 m, whereas water in deeper Area 4 was almost twice as clear (Table 3).

Secchi readings for 1987 were also examined to identify the effects of 2MC and 8MC on suspended sediment in Playgreen Lake. Mean Secchi value (±SD) for the 17 stations south of 8MC was 0.84 m (±0.22), whereas north of the channel the mean was 1.25 m (±0.21). These data show that the northern area was receiving less sediment and probably lower quantities of organic particulates and nutrients. The western third of the southern basin, which receives flow from 2MC, was considerably more turbid than the middle and eastern parts (mean Secchi (m) ±S.D.: west = 0.68 ± 0.14; central = 0.80 ± 0.06; east = 1.03 ± 0.24). North of 8MC, the central third was less turbid than the other two, suggesting that shoreline erosion or resuspension of sediments near shore was occurring.

Håkanson probe results showed that sediments of Playgreen Lake were relatively firm, but became less compacted in a northerly direction (Table 3). When the stations north and south of 8MC were averaged separately, the smallest probe, which penetrates deepest into the benthic habitat, travelled 3.53 ± 1.49 cm (CV = 42.4%) into the sediment in the south, and 8.25 ± 3.23 cm (CV = 39.2%) in the north. Sediment in Kiskittogisu Lake was much looser than in Playgreen Lake. Area 4 had a mean penetration of 24.5 cm, almost eight times that of Area 1 in Playgreen Lake. Area 1 receives continual inflow of water from Lake Winnipeg so fine sediments are likely washed away, whereas the deep, channel-like morphometry of Area 4 of Kiskittogisu Lake may aid deposition and concentration of fine sediments.

Water temperatures in Playgreen and Kiskittogisu lakes have seldom been measured other than during surveys. Because the lakes are shallow and usually well-mixed by the wind, early surveys indicated that they were isothermal during the open-water period, with weak potential for stratification (Koshinsky 1974). Essentially isothermal conditions were also found during the 1987 and 1989 surveys. During these later surveys, the range of temperatures in any profile seldom exceeded 2°C, except when the top 0.5 m warmed in the afternoon. Mean and maximum surface temperatures were higher in 1987 and 1989 than in 1971 or 1972 for both lakes (Table 3), probably a result of higher midsummer air temperatures in recent years (Table 4).

Summer oxygen depletion was not noted in the early surveys at any time in either lake, although winter oxygen conditions were poor in some isolated bays with organic sediments (Koshinsky 1974).

BIOLOGICAL CHANGES

Playgreen Lake

Community differences between areas: Low invertebrate abundances were reported in the 1971 survey (Table 5), probably because samples were hand-picked without magnification (Ayles 1973). However, mean standing stocks in the lake declined about 20% from south to north. (Individual station data from 1971 were not available, so calculation of standard deviations or division into other lake regions could not be done.)

In 1987, not only were numbers of invertebrates substantially higher than in 1971, but areal differences had intensified; for example, Area 3 had only 43% of the standing stock of Area 1 (Table 5). Standing stock in Area 2 was intermediate.

Mean standing stocks in 1989 were considerably lower than in 1987 (Table 5). Numbers of invertebrates in Areas 1 and 2 were reduced to nearly 1/3 of their 1987 values; numbers in Area 3 declined by ≈1/2. The northward reduction in standing stock was still evident, but differences among regions were less.

Mean standing stocks of individual taxa in each of the areas for 1971, 1987, and 1989 are shown in Table 6. In 1971, Amphipoda were usually the most abundant, followed by Mollusca and Ephemeroptera. Diptera and Oligochaeta appeared less frequently than expected, possibly because the sorting techniques missed smaller forms.

In 1987, the basic order of 1971 abundances still held: Amphipoda generally were the most abundant taxon in each area, followed by Mollusca, Diptera, and Ephemeroptera. Oligochaeta and Trichoptera were numerous (499 and 199 $\cdot m^{-2}$) in Area 1, but their numbers diminished in other areas.

In 1989, abrupt change occurred in the abundance ranking of taxa within each area, primarily because of a major decrease in the number of Amphipoda, but also because the relative abundance of Ephemeroptera increased. Dipteran abundance increased slightly from 1987 to 1989 in Area 1, but decreased in Area 2 and Area 3 (Table 5). The largest declines were in the Amphipoda, which dropped by an order of magnitude at most sites; the population of Area 2 decreased by 94%. Molluscs also declined in all areas, although not as sharply as the Amphipoda. Molluscs in Areas 1 and 2 declined to about 30% of their 1987 abundances, but the drop in Area 3 was less drastic. Numbers of Trichoptera also declined in all areas; their abundance in 1989 was only 13-17% of their 1987 values.

Ephemeroptera and the Oligochaeta increased in 1989 compared to 1987. Ephemeroptera increased ≈26% in Area 1, but the population almost doubled in Area 2 and more than tripled in Area 3 (Table 6). Oligochaete numbers declined slightly in Area 1, but like the mayflies, more than doubled in Area 2 and tripled in Area 3.

Communities south and north of the 8MC: Differences in the mean standing stocks of individual taxa in regions of Playgreen Lake south or north of the 8MC are shown in Table 7 (station data are listed in Appendix 1). In 1987, the southern region had significantly more invertebrates than the northern region (11516 vs 4833 organisms m^{-2}). Populations of Amphipoda and Mollusca contributed most of this standing stock: ≈9000 m^{-2} in the south and ≈3300 m^{-2} in the north. Diptera were the next most abundant taxon; both regions had similar numbers (1250 and 1023 m^{-2}). Numbers of Ephemeroptera were ≈400 m^{-2} throughout. By 1989, community composition had changed dramatically in both regions of the lake. Overall, standing stocks declined to 4151 organisms m^{-2} in the south, and 2631 in the north. Diptera and Mollusca dominated in the south, whereas Mollusca and Ephemeroptera dominated in the north. Although molluscan numbers were considerably lower than in 1987, particularly in the south, Amphipoda showed the greatest reduction. In contrast, the Ephemeroptera increased lakewide; their standing stocks more than doubled in the northern region.

Effects of 2MC: Examination of the 1987 mean standing stock in each of the west, central and east sections of the region of Playgreen Lake south of the 8MC revealed that the western section, which is located in the sediment plume from 2MC, was more productive than either of the central or eastern sections (13100 vs ≈10600 organisms$\cdot m^{-2}$). A similar, but weaker relationship was observed in 1989 when one eastern station with anomalously high standing stocks was deleted (West: 4212; Central: 2196; East: 3777 organisms m^{-2}). The region north of 8MC showed no significant differences between west, central and east sections in either of the years of survey.

Kiskittogisu Lake

In 1971, mean standing stocks in Areas 4 and 5 were almost identical, despite the low numbers found (Table 5). In 1989, this similarity had disappeared; standing stock in Area 5 which receives direct inflow from 8MC was 68% higher than in the more remote Area 4. In 1971, the order of abundance of individual taxa in Area 4 was: Mollusca > Ephemeroptera > Amphipoda (Table 8). Diptera and Oligochaeta were rare. In Area 5, the order of abundance was: Ephemeroptera > Amphipoda > Mollusca. The 1989 survey revealed shifts in abundance in Area 4: Ephemeroptera > Diptera > Amphipoda > Mollusca. Oligochaetes occurred more frequently than in 1971, but the high standard error indicated that their distribution was sporadic. Area 5 did not show the same changes seen in Area 4; here, the order of abundance was Ephemeroptera > Mollusca > Diptera. Numbers of Amphipoda were particularly low, even compared to Area 4, and were similar to the Oligochaetes, which were found for the first time in Area 5. Like Area 4, the high standard error value indicated that oligochaete distribution was variable; a similar conclusion could be made for the Amphipoda.

Results of Multidimensional Scaling (MDS)

Shepard diagrams of station coordinates derived from MDS were graphed for Playgreen Lake in 1987 (Fig. 3A) and for Playgreen and Kiskittogisu lakes in 1989 (Fig. 3B) to delineate station similarities. In 1987 (Playgreen Lake only), stations generally clustered into two groups: those north of 8MC, and those south of 8MC (Fig. 1). One station, N17, which lies immediately north of 8MC, was similar to the southern station cluster. Two stations (S11 and N33) were classified in an area of overlap; they had taxa and abundances characteristic of both clusters. Four widely scattered stations (S13, N18, N21, N28) fell outside both clusters; their exclusion was attributable to the absence of Gastropoda from only these stations.

Similar analysis of the 1989 data (Fig. 3B) showed that the stations within Playgreen Lake clustered in approximately the same manner as in 1987 (north and south of 8MC), but the clusters were more diffuse, and more stations occupied an overlap area between north and south clusters. Stations N15 and N17, both located on the transect just north of 8MC (see Fig. 1), fell barely within, or just outside the cluster of

southern stations. Stations from Kiskittogisu Lake formed a group "perpendicular" to the orientation of Playgreen Lake groups, overlying both of the regions of Playgreen Lake, and indicating that Kiskittogisu Lake stations had faunal compositions similar to both areas of Playgreen Lake. Stations from the northern part of Kiskittogisu Lake (Area 4) generally fell within the northern Playgreen Lake cluster, but stations from Area 5 of Kiskittogisu Lake clustered outside of Playgreen Lake south of 8MC. Stations K45 and K50 were in the overlapping area between Playgreen Lake clusters, and some stations (K41, K46) lay outside all clusters.

DISCUSSION

EFFECTS OF LAKE WINNIPEG REGULATION

Instabilities develop in benthic invertebrate lake communities when two conditions pertain: (1) the lake is flooded deeper than the maximum high water level; and (2) reversed seasonal water level changes produce vegetational destruction in the littoral zone (Sjörs 1984). The storage reservoir created by the Jenpeg dam on the lower Nelson River includes Lake Winnipeg, Playgreen Lake and Kiskittogisu Lake. This reservoir was formed with only a minor increase in the mean water level, and minimal erosion has been associated with the water level increase. The large size of the reservoir permits an operating regime of late fall-winter drawdown which has never been sufficiently severe to destroy littoral macrophyte beds by exposure. However, the effects of regulation on Cross Lake below the Jenpeg dam are quite different (Gaboury and Patalas 1984).

The increase in water level of Playgreen Lake was within the normal annual range, and the increase in Kiskittogisu Lake was only slightly above the maximum high water level, so the effect of flooding on the benthic community was expected to be minimal. When pre-regulation benthic invertebrate data from Playgreen Lake are compared to post-regulation data, the abundance ranking of the different taxa is almost identical. This contrasts with the results of studies of flooded lakes in Sweden (Lindström 1973). However, the Swedish lakes were severely flooded and have winter drawdowns of 20-30 m. Effects on the benthos and the fisheries were dramatic because of destruction of the littoral benthic fauna and of fish eggs that were spawned in shallow water.

The flow of water entering the southern basin (Area 1) of Playgreen Lake has not been impeded since regulation; in fact, construction of 2MC has augmented the flow out of Lake Winnipeg, particularly during low-water periods. Consequently, the benthic invertebrate community south of 8MC is still similar to its pre-impoundment condition. This region of the lake is still the most productive and diverse, and probably reflects the stabilizing influence of the large mass of water in Lake Winnipeg.

EFFECTS OF 2MC ON PLAYGREEN LAKE

Koshinsky (1974) predicted that the input of sediments from Lake Winnipeg through 2MC could have consequences for the benthic invertebrates in Playgreen Lake, but could not make specific predictions due to the high levels of suspended sediment already prevailing. He also suggested that reduction of flow through Warren Landing would enhance ephemeropteran populations in the extreme southern end of Playgreen Lake. Although a slight effect of the 2MC on Playgreen Lake benthos was apparent, direct comparisons to the 1971 data were impossible in the absence of data from individual stations. Secchi readings showed the presence of a plume of suspended material that lowered transparency on the western side of Playgreen Lake north of 2MC; invertebrate populations were generally higher along this plume. This indicates an enhancement of the benthic populations by the augmented flow from this channel, possibly by the addition of sedimenting particulate organic material (Simons 1979; Armitage 1982). Because the plume of sediment (see Plate 2, Electromagnetic Sensing and Interpretation 1987) probably contains organic material washed from the shores of Lake Winnipeg, including forest litter, sphagnum mosses and peat, and living and dead phytoplankton, it provides a source of sustenance for benthic invertebrates. In addition to large, visible organic particles, dissolved fractions such as low-molecular-weight organic acids and polypeptides are probably also present (Lind 1971). Mean density of bottom fauna can decrease with increasing distance from the inlet to a reservoir, and Edmonds and Ward (1979) suggested that some allochthonous detritus may play a more important role than phytoplankton productivity in the benthic community of reservoirs.

EFFECTS OF 8MC ON PLAYGREEN AND KISKITTOGISU LAKES

Decreases in the volume of water entering a lake or river because of upstream diversion of the flow are known to result in a lowered abundance of benthic invertebrates. For example, construction of the Missi Falls dam on the Churchill River at the outlet of Southern Indian Lake reduced not only the area of the downstream lakes by exposing much of the littoral zone, but also reduced the numbers of invertebrates in the profundal zones (A.P. Wiens and D.M. Rosenberg, unpublished data). The portion of Playgreen Lake that lies north of 8MC appears to have suffered a decrease in the standing stock of benthic invertebrates following construction of the diversion into Kiskittogisu Lake. Although invertebrate

standing stock in Area 3 was ≈84% of that in Area 1 in the 1971 study, the standing stocks of Area 3 in 1987 and 1989 were only 43 to 60% of those in Area 1. The significant diversion of water away from the northern areas of Playgreen Lake likely has removed nutrients and food that were formerly available to the benthos. All of the taxa examined were similarly affected, but the decline was greater for the Amphipoda than for the other groups.

Headwater lakes and lakes without significant inflows generally have lower benthic abundances than lakes with riverine flows and faster renewal times (Hruska 1973). For example, lakes isolated from the flow of the Churchill River generally had fewer macroinvertebrates than lakes directly influenced by the flow (Hamilton 1974; Baxter 1977); areas of Southern Indian Lake isolated from the flow of the Churchill River usually had fewer invertebrates than areas directly affected by the flow (Wiens and Rosenberg 1984).

Although the northern portion of Kiskittogisu Lake received some of the flow from the Nelson River prior to 8MC, the large, open basin in the southwest was effectively isolated. It received only runoff from its own catchment, mostly drainage from the western bog areas. This small amount of inflow was offset somewhat by the shallowness of the basin to yield a renewal time of 600+ days. Total numbers of benthic invertebrates in each area of Kiskittogisu Lake were almost identical in the 1971 surveys, but Kiskittogisu Lake overall had lower productivity than Playgreen Lake.

Koshinsky (1974) predicted that the new water regime would favour benthic invertebrate productivity in Kiskittogisu Lake, because flows directly from Lake Winnipeg would augment the loading of nutrients, algae and allochthonous organic matter. When Kiskittogisu Lake was resurveyed 13 yr after 8MC became operational, Area 4 still had the lowest standing stocks of macroinvertebrates of all the areas examined in this study, but the effects of the added inflow to Area 5 were particularly noticeable. With an estimated renewal time of 23 d, still the longest of any of the areas examined (Table 1), particulate settling and food enhancement caused an increase in abundance of invertebrates in Area 5 relative to Area 4. Invertebrates in Area 5 probably also benefitted from increased primary productivity caused by enhanced nutrients in the inflow.

Koshinsky (1974) also predicted that standing stocks of benthic organisms in Kiskittogisu Lake would become similar to those of Playgreen Lake south of 8MC. Our comparisons of community similarities in Playgreen Lake with those of Kiskittogisu Lake do not reveal the close similarities expected, especially for the open, southern basin of Kiskittogisu Lake. Boon (1988) stated that lakes receiving diversion inflows developed benthic communities similar to the donor lake because of the importation of donor lake nutrients and biota. Although 8MC provides rapid and convenient access to new habitats, particularly in Area 5, for forms originating in upstream areas, the expected taxonomic similarities have not developed to date.

DECLINES OF STANDING STOCK: 1987-1989

The decline in total numbers of benthic invertebrates in Playgreen Lake between 1987 and 1989 was probably related to drought conditions across the prairie region in 1988-1989. Reduced spring and summer flows through the southern basin of Playgreen Lake and above normal air temperatures in northern Manitoba produced higher-than-normal water temperatures in the lake. Reduced summer flows also caused higher temperatures in Norwegian rivers after regulation (Lillehammer and Saltveit 1984).

The decline in standing stocks was particularly noticeable in taxa favouring cool lake waters, such as the Amphipoda (Bousfield 1958) and some of the sphaeriid Molluscs (Mackie et al. 1980). However, taxa such as the oligochaetes and burrowing mayflies known to thrive in warm, shallow habitats (Ward and Stanford 1979; Extence 1981), benefitted by the increased warmth and/or the reduced flow.

CONCLUSIONS

1. Regulation of water level has had little effect on the benthic invertebrates of Playgreen and Kiskittogisu lakes, the majority of effects were related to changes in the flow regime caused by 2MC and 8MC.
2. Benthic invertebrate standing stocks within the sediment plume from 2MC in Playgreen Lake were slightly higher than in areas adjacent to the plume.
3. The abundance of benthic invertebrates, particularly Amphipoda, in Playgreen Lake north of 8MC has decreased since the diversion of flows through 8MC began, possibly because of lessened inputs of nutrients and particulate organic matter to the northern region.
4. Benthic invertebrate populations have increased in abundance in the southern basin of Kiskittogisu Lake; it now receives nutrient-laden flow from Playgreen Lake through 8MC.
5. Drought conditions in 1988-1989, which reduced water flows and were linked to higher-than-normal summer air and water temperatures may explain reduced benthic abundances from 1987 to 1989 in Playgreen

Lake, particularly of the Amphipoda and sphaeriid molluscs.

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REFERENCES

ARMITAGE, P.D. 1982. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities, p. 139-165. In A. Lillehammer and S.J. Saltveit (ed.) Regulated rivers. Colombia University Press, Irvington-on-Hudson. 540 p.

AYLES, H.A. 1973. The limnology-fisheries of Playgreen and Kiskittogisu Lakes, Manitoba. Part II. Morphology, biology, and fisheries. Manitoba Hydro System Planning Division Report, April, 1973. 51 p.

BAXTER, R.M. 1977. Environmental effects of dams and impoundments. Annu. Rev. Ecol. Syst. 8: 255-283.

BOON, P.J. 1988. The impact of river regulation on invertebrate communities in the U.K. Regul. Rivers Res. Manage. 2: 389-409.

BOUSFIELD, E.L. 1958. Fresh-water amphipod crustaceans of glaciated North America. Can. Field-Nat. 72: 55-113.

DICKSON, I.W. 1975. Hydroelectric development of the Nelson River system in northern Manitoba. J. Fish. Res. Board Can. 32: 106-116.

EDMONDS, J.S., and J.V. WARD. 1979. Profundal benthos of a multibasin foothills reservoir in Colorado, U.S.A. Hydrobiologia 63: 199-208.

ELECTROMAGNETIC SENSING AND INTERPRETATION. 1987. Remote sensing imagery catalogue, with applications to environmental monitoring in northern Manitoba. Northern Flood Agreement Ecol. Rep. Series 87-3: 554 p.

ENVIRONMENT CANADA. 1972. Monthly record of meteorological observations, p. 31, April-September. Temperature and precipitation summaries (Manitoba). Atmospheric Environment Service, Environment Canada, Toronto, ON.

ENVIRONMENT CANADA. 1988-1990. Monthly record of meteorological observations in Canada. REF 008. April-September. Monthly summary (temperature). Atmospheric Environment Service, Downsview, ON. (Microfiche)

EXTENCE, C.A. 1981. The effect of drought on benthic invertebrate communities in a lowland river. Hydrobiologia 83: 217-224.

GABOURY, M.N., and J.W. PATALAS. 1984. Influence of water level drawdown on the fish populations of Cross Lake, Manitoba. Can. J. Fish. Aquat. Sci. 41: 118-125.

HAMILTON, A.L. 1974. Zoobenthos survey of Southern Indian Lake. Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1971-1975. Tech. Rep. Append. 5. Fish. Limnol. Stud. 1G: 32 p.

HECKY, R.E., R.W. NEWBURY, R.A. BODALY, K. PATALAS, and D.M. ROSENBERG. 1984. Environmental impact prediction and assessment: the Southern Indian Lake experience. Can. J. Fish. Aquat. Sci. 41: 720-732.

HRUSKA, V. 1973. The changes of benthos in Slapy Reservoir in the years 1960-1961. Hydrobiol. Stud. 2: 213-247.

KOSHINSKY, G.D. 1974. The limnology-fisheries of the outlet lakes area: present conditions and implications of hydroelectric development. Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1971-1975. Tech. Rep. Append. 5. Fish. Limnol. Stud. 2A: 156 p.

LILLEHAMMER, A., and S.J. SALTVEIT. 1984. The effect of the regulation on the aquatic macroinvertebrate fauna of the river Suldalslagen, Western Norway, p. 201-210. In A. Lillehammer and S.J. Saltveit (ed.) Regulated rivers. Colombia University Press, Irvington-on-Hudson. 540 p.

LIND, O.T. 1971. The organic matter budget of a central Texas reservoir, p. 193-202. In G.E. Hall (ed.) Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8: 511 p.

LINDSTRÖM, T. 1973. Life in a lake reservoir: Fewer options, decreased production. Ambio 2: 145-153.

MACKIE, G.L., D.S. WHITE, and T.W. ZDEBA. 1980. A guide to freshwater mollusks of the Laurentian great lakes with special emphasis on the genus Pisidium. U.S. Environ. Prot. Agency Rep. EPA-600/3-80-068: 144 p.

MACLAREN PLANSEARCH INC. 1985. Ecological study of Playgreen Lake, Manitoba. Report to Manitoba Hydro. 6 Chap.

NEWBURY, R.W., G.K. MCCULLOUGH, and R.E. HECKY. 1984. The Southern Indian Lake impoundment and Churchill River diversion. Can. J. Fish. Aquat. Sci. 41: 548-557.

SEBASTIEN, R.J., D.M. ROSENBERG, and A.P. WIENS. 1988. A method for subsampling unsorted benthic macroinvertebrates by weight. Hydrobiologia 157: 69-75.

SIMONS, D.B. 1979. Effects of stream regulation on channel morphology, p. 95-111. In J.V. Ward and J.A. Stanford (ed.) The ecology of regulated streams. Plenum Press, New York. 398 p.

SJÖRS, H. 1984. Hydro-electric development as a set of ecological factors, p. 133-136. In A. Lillehammer and S.J. Saltveit (ed.) Regulated rivers. Colombia University Press, Irvington-on-Hudson. 540 p.

STOCKNER, J.G. 1973. The limnology of Playgreen and Kiskittogisu Lakes, Manitoba. Part I. Physical and chemical features. Manitoba Hydro Manuscript Report. 18 p.

WARD, J.V., and J.A. STANFORD. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams, p. 35-55. In J.V. Ward and J.A. Stanford (ed.) The ecology of regulated streams. Plenum Press, New York. 398 p.

WATER SURVEY OF CANADA. 1987a. Historical streamflow summary. Manitoba to 1986. Environment Canada, Water Resources Branch, Ottawa, ON. 275 p.

WATER SURVEY OF CANADA. 1987b. Surface water data. Manitoba 1986. Environment Canada, Water Resources Branch, Ottawa, ON. 185 p.

WATER SURVEY OF CANADA. 1988. Surface water data. Manitoba 1987. Environment Canada, Water Resources Branch, Ottawa, ON. 188 p.

WATER SURVEY OF CANADA. 1989. Surface water data. Manitoba 1988. Environment Canada, Water Resources Branch, Ottawa, ON. 185 p.

WATER SURVEY OF CANADA. 1990. Surface water data. Manitoba 1989. Environment Canada, Water Resources Branch, Ottawa, ON. 183 p.

WIENS, A.P., and D.M. ROSENBERG. 1984. Effect of impoundment and river diversion on profundal macrobenthos of Southern Indian Lake, Manitoba. Can. J. Fish. Aquat. Sci. 41: 638-648.

WILKINSON, L. 1986. SYSTAT: the system for statistics. SYSTAT Inc., Evanston, IL. 18 Chap. and Append.

Table 1. Morphometry of Playgreen and Kiskittogisu lakes (adapted from Ayles 1973 and Koshinsky 1974). See Fig. 1 for area designations.

Parameter	Area:	Playgreen 1	2	3	Kiskittogisu 4	5
Surface area (km^2)		330.78	91.41	249.31	44.99	220.74
			Total = 671.50		Total = 265.73	
Mean depth (m)		2.96	3.93	2.59	7.07	3.60
			Lakewide = 2.96		Lakewide = 4.18	
Max. depth (m)		6.10	17.07	18.59	32.00	27.40
Volume (km^3)		0.940	0.354	0.615	0.296	0.748
			Total = 1.909		Total = 1.044	
Renewal time (d)						
Before regulation		6.3	2.4	4.1	2.0	600+
			Total = 12.8		Total = 600+	
After regulation[1]		8.1	4.4	8.3	2.4	22.8
			Total = 20.8		Total = 25.2	

[1] Based on historical streamflow summaries for the Nelson River, 1976-1987 (Water Survey of Canada 1987a,b, 1988).

Table 2. Mean monthly discharge (m^3sec^{-1}) at Jenpeg on the West Channel of the Nelson River during benthic survey years (Water Survey of Canada 1987, 1988, 1989).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1972[a]	1810	1770	1850	2050	2750	2980	2780	2600	2340	2160	1910	1700	2230
1987	2070	1970	1770	1450	944	533	614	647	1020	1540	1590	1670	1310
1989	1240	1150	1090	887	782	643	815	1170	1580	1870	1860	1850	1250

[a] 1971 discharge records incomplete.

Table 3. Secchi disk, Håkanson Sediment Penetrometer (HSP) and temperature measurements of Playgreen and Kiskittogisu Lakes during the surveys of 1970-72 (Ayles 1973; Koshinsky 1974), 1987 and 1989.

Measurement	Playgreen L. Areas 1	2	3	Lake Mean	Kiskittogisu L. Areas 4	5	Lake Mean
Secchi disk (m)							
Mean (range) 1970 - 1972	---	---	---	0.49-0.55 (0.15-1.43)	---	---	0.30-0.76 (0.21-1.46)
1987	0.85 (0.45-1.20)	0.91 (0.60-1.10)	1.32 (1.05-1.60)	1.04 (0.45-1.60)	---	---	---
1989	0.85 (0.80-1.00)	0.89 (0.80-1.00)	0.84 (0.60-1.00)	0.86 (0.60-1.00)	0.73 (0.60-0.80)	0.40 ---	0.48 (0.40-0.80)
HSP penetration (Small probe[1])							
Mean (max.)(cm)	3.2(6.2)	5.9(13.6)	8.7(12.7)	---	24.5(32.0)	11.3(22.0)	---
Mean water temp (°C)							
1971	18.1	18.0	17.5	19.8(max.)	16.3	16.8	17.7(max.)
1987	23.0	22.7	22.0	25.5(max.)	---	---	1972: 19.4(max.) ---
1989	23.0	24.5	24.8	27.1(max.)	24.7	24.2	25.3(max.)

[1] The HSP has three probes; the smallest probe penetrates deepest.

Table 4. Mean monthly air temperatures (°C) at Norway House on the East Channel of the Nelson River during and between benthic survey years (Environment Canada 1972, 1988, 1989, 1990).

Year	May	June	July	August	September
1971	12.4	16.3	16.1	17.8	11.7
1987	10.4	17.3	17.6	15.5	11.4
1988	9.2	18.4	19.3	16.7	11.2
1989	9.2	14.7	21.7	17.7	9.9

Table 5. Mean standing stock (no.·m^{-2} (± S.E.)) of invertebrates in Playgreen and Kiskittogisu lakes. Area designation and 1971 survey data from Ayles (1973). NS = not sampled.

Year	Playgreen Areas			Kiskittogisu Areas	
	1	2	3	4	5
1971	502	437	419	212	209
1987	11558 (1548)	8667 (1687)	4941 (419)	NS	NS
1989	4417 (1161)	3223 (499)	2654 (184)	2087 (191)	3496 (527)

Table 6. Mean standing stock (no.·m^{-2} ± (S.E.)) of benthic invertebrates in Areas 1-3 of Playgreen Lake in 1971, 1987 and 1989. Oligo.= Oligochaeta, Ephem. = Ephemeroptera, Misc. = Miscellaneous.

	Year	Diptera	Amphipoda	Oligo.	Mollusca	Ephem.	Trichoptera	Misc.
AREA 1	1971	15	201	1	170	98	12	6
	1987	1603 (499)	5586 (1459)	499 (255)	2989 (632)	437 (141)	199 (34)	245 (72)
	1989	1880 (1163)	658 (361)	385 (172)	896 (168)	553 (152)	27 (11)	17 (6)
AREA 2	1971	0	141	0	251	33	11	1
	1987	829 (136)	3053 (759)	70 (40)	3883 (1391)	584 (130)	78 (28)	170 (52)
	1989	525 (65)	184 (104)	167 (79)	1298 (579)	1010 (200)	11 (6)	29 (11)
AREA 3	1971	22	238	1	117	34	4	3
	1987	976 (95)	2186 (333)	8 (3)	1469 (209)	253 (54)	41 (9)	8 (5)
	1989	317 (28)	191 (71)	28 (15)	1299 (208)	793 (76)	7 (3)	19 (6)

Table 7. Mean abundance of benthic invertebrate taxa (mean no.·m^{-2} (±S.E.)) found in the regions south or north of the 8 mile channel in Playgreen Lake in 1987 and 1989. (South = sites 1-17; North = sites 18-33). Mollusca: ≈80% Pelecypoda and ≈20% Gastropoda; Ephem. = Ephemeroptera, Trich. = Trichoptera.

Year	Region	Diptera	Amphipoda	Oligochaeta	Mollusca	Ephem.	Trich.	Misc.	Total
1987	South	1250 (341)	5073 (1001)	355 (171)	3993 (839)	423 (98)	171 (27)	421 (77)	11516 (1298)
	North	1023 (85)	1998 (293)	15 (8)	1341 (175)	405 (93)	35 (8)	51 (15)	4833 (335)
1989	South	1410 (757)	513 (242)	341 (117)	1261 (339)	576 (116)	23 (8)	49 (15)	4151 (827)
	North	360 (41)	165 (54)	27 (11)	1061 (190)	995 (110)	6 (3)	22 (8)	2631 (159)

Table 8. Mean standing stock (no.·m^{-2} ± (S.E.)) of benthic invertebrate taxa in Areas 4 and 5 of Kiskittogisu Lake in 1971 and 1989. Oligo. = Oligochaeta, Ephem. = Ephemeroptera, Misc. = Miscellaneous.

Year	Diptera	Amphipoda	Oligo.	Mollusca	Ephem.	Trichoptera	Misc.
AREA 4							
1971	8	49	2	85	55	0	7
1989	502 (118)	330 (183)	49 (36)	259 (129)	916 (124)	0 (11)	32 (16)
AREA 5							
1971	8	68	0	36	97	0	0
1989	431 (89)	139 (114)	135 (65)	1267 (232)	1503 (350)	4 (5)	16 (13)

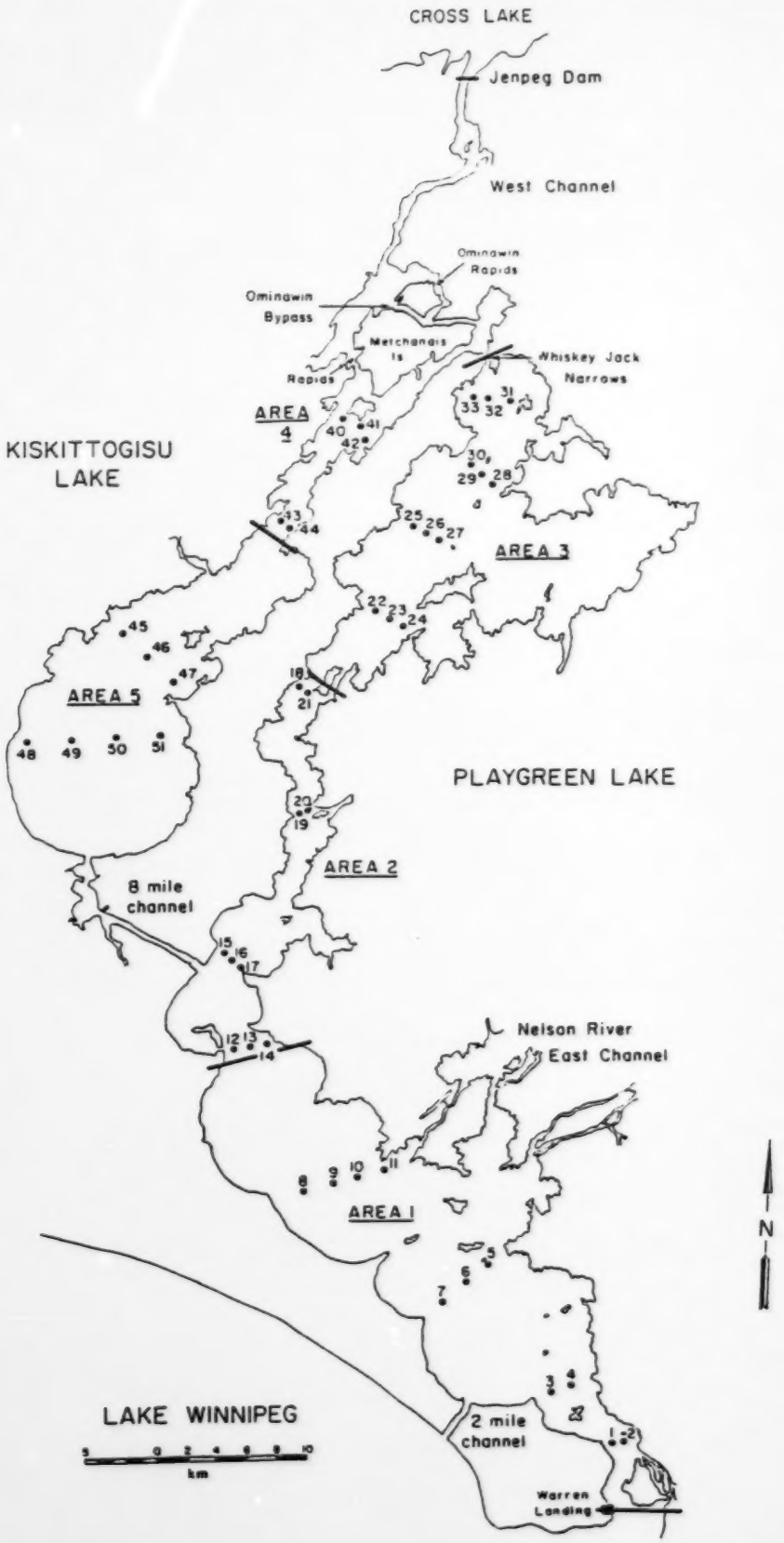

Fig. 1. Benthic invertebrate sampling sites in surveys of Playgreen (1987, 1989) and Kiskittogisu (1989) lakes.

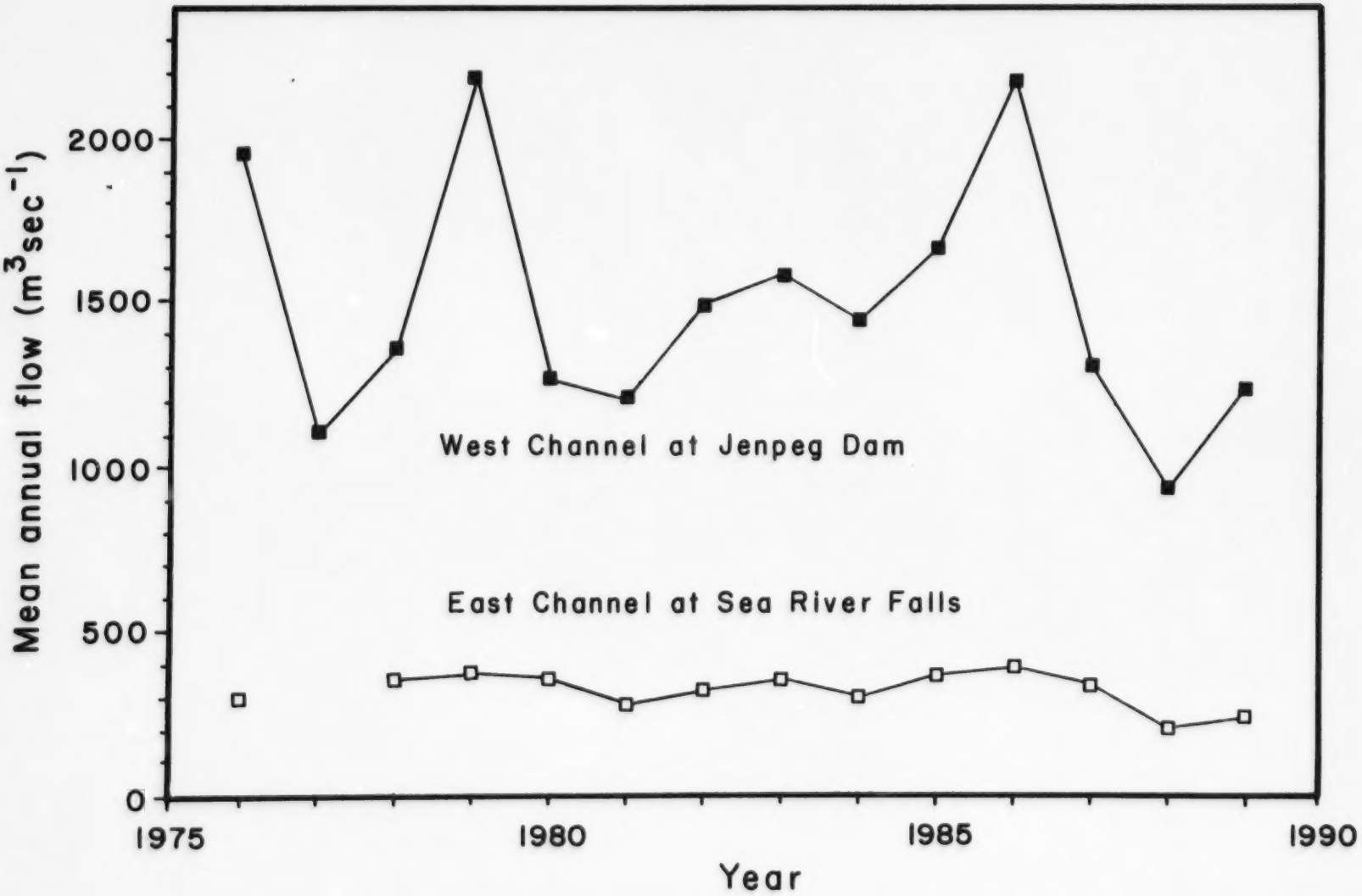

Fig. 2. Discharge of the East and West Channels of the Nelson River, Manitoba, 1976-1989 (Water Survey of Canada 1987a,b, 1988-1990).

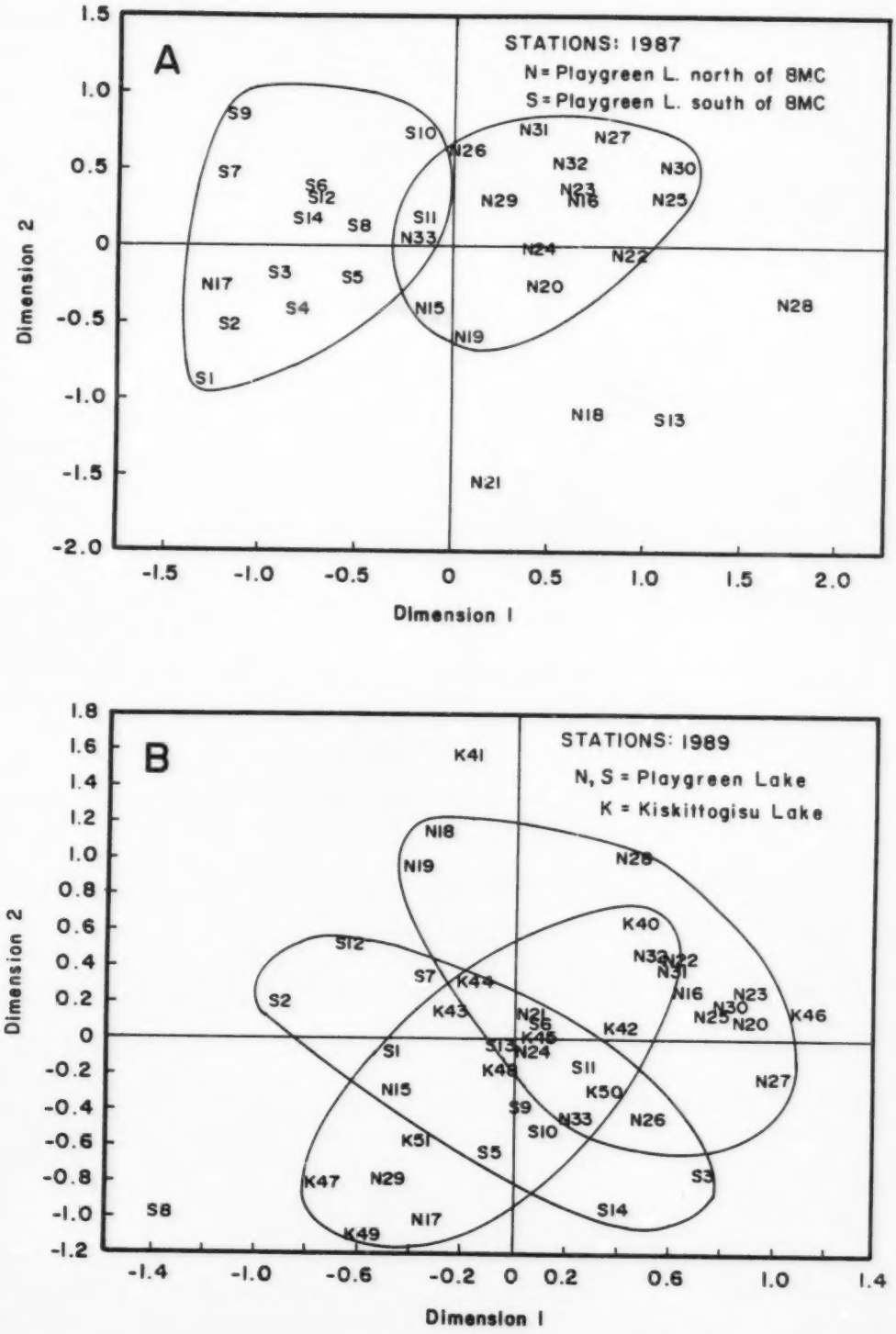

Fig. 3. Plots of station coordinates from multidimensional scaling of Euclidean distances based on taxon abundances in Playgreen and Kiskittogisu lakes. A: 1987 Playgreen Lake sites, labelled north (N) and south (S) of 8 mile Channel (8MC). B: 1989 Playgreen Lake stations as given, Kiskittogisu Lake stations labelled K. (See Figure 1. for station locations).

APPENDIX 1.

Results of two invertebrate surveys of Playgreen Lake. Stations are listed in order of proximity to geographic locations. Data represent means of three replicates expressed as no.·m^{-2}. Abbreviations: Stn = Station; Secc = Secchi disk reading; Chiro = Chironomidae; Cerat = Ceratopogonidae; Amphi = Amphipoda; Oligo = Oligochaeta; Pelec = Pelecypoda; Gast = Gastropoda; Ephem = Ephemeroptera; Tri = Trichoptera. Depth and Secchi disk reading are given in metres.

A. 1987 Survey

Stn	Depth	Secc	CHIRO	CERAT	AMPHI	OLIGO	PELEC	GAST	EPHEM	TRI	OTHER	TOTAL
Warren Landing												
1	11.0	0.8	5791	315	1634	2967	1448	29	831	158	344	13516
2	7.0	0.8	1175	373	645	530	6407	301	1003	201	502	11137
3	4.9	0.8	2695	115	9761	186	1405	1018	1204	186	129	16698
4	4.0	0.8	1347	315	4501	344	4142	301	932	287	29	12198
5	1.9	1.5	1362	158	1433	172	1003	760	487	129	14	5518
6	3.0	0.8	645	72	13760	172	4415	774	29	57	43	19966
7	2.1	0.5	831	14	13459	588	201	100	14	459	172	15838
8	2.9	0.6	717	29	3483	29	1433	373	86	115	401	6665
9	3.0	0.7	874	0	7625	487	5289	129	29	301	774	15508
10	3.7	0.9	616	14	3741	0	1491	917	29	186	201	7195
11	3.7	1.2	158	14	1405	14	674	272	158	115	86	2895
12	3.0	0.6	325	49	6044	92	7138	2081	77	29	143	15979
13	4.3	0.8	301	0	889	0	731	0	72	172	373	2537
14	3.7	0.9	315	29	6794	57	4601	2795	444	57	344	15437
15	3.7	0.9	579	123	5310	0	3169	105	397	115	292	10090
16	7.3	0.9	889	14	4357	0	1218	229	573	57	0	7339
17	2.7	1.0	770	234	1399	404	11223	1720	833	278	396	17257
8-mile Channel												
18	9.1	1.0	1534	100	2394	14	330	0	559	43	0	4974
19	4.3	1.1	873	288	358	0	1290	209	1269	14	109	4411
20	7.0	1.1	1089	72	2523	0	788	29	416	14	14	4945
21	6.4	1.0	602	100	459	129	1175	0	1204	0	29	3698
22	4.3	1.1	1132	14	1433	29	874	315	674	0	0	4472
23	3.4	1.3	1419	14	1634	0	1663	487	430	43	0	5690
24	3.0	1.1	1104	14	1792	29	774	86	487	43	0	4329
25	3.5	1.2	774	14	3641	0	616	272	186	0	0	5504
26	3.4	1.3	702	0	4558	14	1634	602	72	72	14	7668
27	3.7	1.3	659	0	3082	0	1276	215	115	57	0	5404
28	5.5	1.4	545	0	674	0	72	0	129	14	0	1433
29	2.4	1.5	731	29	803	0	1720	416	129	72	14	3913
30	3.2	1.6	1003	0	2035	14	416	301	215	0	0	3985
31	3.5	1.6	874	0	1720	0	1333	1018	143	29	14	5131
32	5.3	1.6	1003	14	2924	0	1003	674	115	72	0	5805
33	2.7	1.2	1634	29	1935	14	1462	401	344	86	57	5963
Whiskey Jack Narrows												

B. 1989 Survey

Stn	Depth	Secc	CHIRO	CERAT	AMPHI	OLIGO	PELEC	GAST	EPHEM	TRI	OTHER	TOTAL
Warren Landing												
1	12.0	0.8	689	430	546	517	804	143	1364	14	14	4522
2	7.8	0.8	258	273	100	890	57	29	646	14	0	2268
3	5.0	0.8	1378	186	2555	158	1091	387	1579	14	0	7348
4	1.6	0.9	13363	57	0	1909	14	0	0	14	72	15430
5	1.7	0.9	1077	172	100	129	717	431	273	57	29	2985
6	2.7	0.9	344	14	244	43	560	172	488	0	14	1880
7	2.1	1.0	359	72	3488	129	244	215	646	14	14	5180
8	3.0	0.8	1263	0	0	344	416	316	29	129	0	2497
9	4.1	0.8	143	14	72	57	416	890	301	14	14	1923
10	3.5	0.8	301	0	43	29	962	818	488	29	29	2699
11	4.0	0.8	273	14	86	29	172	1005	272	0	0	1851
12	2.7	0.8	201	43	1105	330	172	72	57	0	0	1980
13	4.3	1.0	445	14	72	86	258	373	416	0	14	1680
14	2.9	1.0	617	0	72	14	2584	3574	201	43	86	7191
15	3.9	1.0	703	29	57	373	1191	172	1120	14	86	3745
16	5.2	0.9	503	43	172	0	560	330	1177	0	14	2799
17	2.9	0.9	675	14	14	761	1134	1163	732	43	57	4593
8-mile Channel												
18	8.5	0.8	359	0	57	29	72	0	1708	0	0	2224
19	4.3	0.8	316	14	57	43	215	0	1607	0	14	2267
20	8.2	0.9	373	14	186	0	244	158	1263	14	0	2253
21	5.0	0.8	875	14	43	29	560	143	1823	0	14	3502
22	4.2	0.6	359	0	43	0	560	215	1119	0	72	2368
23	3.5	0.6	330	14	86	0	919	57	1091	14	0	2512
24	3.1	0.6	301	0	43	43	675	502	1005	0	14	2583
25	3.3	0.9	258	57	258	0	1378	431	789	0	14	3186
26	3.4	0.9	229	0	675	129	1321	560	431	0	0	3344
27	3.5	0.9	215	0	703	0	1938	732	402	14	14	4019
28	6.5	1.0	589	0	0	0	272	29	1163	0	14	2067
29	2.4	0.9	258	14	0	144	1077	904	588	0	14	3000
30	3.0	1.0	301	0	215	0	387	273	875	29	0	2080
31	3.5	1.0	301	14	143	0	832	115	775	0	29	2210
32	3.2	0.9	244	0	57	0	488	72	703	0	29	1593
33	2.7	0.8	301	14	72	14	1363	488	574	29	29	2885
Whiskey Jack Narrows												

APPENDIX 2.

Results of the 1989 benthic invertebrate survey of Kiskittogisu Lake. Stations are listed in order of proximity to geographic locations. Data represent means of three replicates expressed as no.·m^{-2}. Abbreviations: Stn = Station; Secc = Secchi disk reading; Chiro = Chironomidae; Cerat = Ceratopogonidae; Amphi = Amphipoda; Oligo = Oligochaeta; Pelec = Pelecypoda; Gast = Gastropoda; Ephem = Ephemeroptera; Tri = Trichoptera. Depth and Secchi disk reading are given in metres.

Stn	Depth	Secc	CHIRO	CERAT	AMPHI	OLIGO	PELEC	GAST	EPHEM	TRI	OTHER	TOTAL
Whiskey Jack Narrows												
40	4.1	0.8	388	29	43	0	158	43	1177	0	43	1881
41	7.0	N/A	416	0	1005	29	14	0	617	0	57	2138
42	4.7	0.8	201	14	273	14	531	186	675	0	0	1894
43	8.2	0.7	761	0	29	86	115	72	1120	0	29	2212
44	10.0	0.6	689	14	301	115	100	72	990	0	29	2310
45	4.0	0.4	201	0	29	29	560	258	2339	0	14	3430
46	4.1	0.4	761	0	761	0	990	488	3187	0	0	6187
47	3.1	0.4	345	14	0	258	890	373	1780	14	86	3760
48	4.0	0.4	503	0	143	186	732	488	875	0	0	2927
49	4.5	0.4	603	0	0	445	1091	1106	789	0	0	4034
50	4.8	0.4	287	0	43	14	546	474	890	14	0	2268
51	4.0	0.4	301	0	0	14	359	517	660	0	14	1865
8-mile Channel												